1 Introduction to the NDT problem

Minor changes to the grain micro-structure or crystallographic orientation of advanced engineering alloys can have a significant effect on the mechanical and thermal properties of the alloy [1], for example changes in primary and secondary angles in a single crystal nickel turbine [2] yielded different stress responses from the same force depending on the direction.

Spatially Resolved Acoustic Spectroscopy (SRAS) is an Non-Destructive Evaluation (NDE) measurement technique which directly measures the elastic properties of the surface of an optically smooth material.

One of the most common application for SRAS is in determining the crystallographic orientation of a surface grain [3, 4, 5] as that can be directly deduced from measuring the elastic properties of the crystal.

2 Aims and Objectives

In this project I aim to improve the resolution at which the velocity of a surface acoustic wave (SAW) point grain propagating on a point grain in a metal can be measured using optical transducers, in order to to this one must overcome a few limitations.

The first limitation is with the frequency at which acoustic waves can be generated; Surface Acoustic Waves are generated on the surface of a metal using a fringe pattern that has been projected by a pulsed laser passing through a an Spatial Light Modulator (SLM) grating, The velocity v_s of the Surface Acoustic Wave (SAW) is calculated using equation-(1) [4] where f_s is the frequency of the the acoustic wave, and λ_g is the separation distance of the grating.

$$v_s = f_s \lambda_g \tag{1}$$

Arc shaped masks can be used in order to focus acoustic waves to a point [6, 7], this can also be done using a moving grating, an Spatial Light Modulator (SLM) [8], or a computer generated hologram [9]. Additionally arc shaped fringe can be generated for more focused Surface Acoustic Wave (SAW) this has the advantage of improved signal to noise ratio (SNR). Unfortunately one of the biggest limitations with the the generation frequency lies with the Abbe diffraction limit.

$$d = \frac{\lambda}{2\text{NA}} \tag{2}$$

One way in which I intend to increase the frequency of the generated ultrasound waves is by using a an ultrafast, modelocked lasers with shorter pulse widths. By shortening the pulse width, the area of the Heat Affected Zone (HAZ) is reduced [10] meaning a smaller fringe pattern can be projected onto the metal, leading to shorter Surface Acoustic Wave (SAW) wavelengths; Additionally, shorter pulse widths allows, for higher repetition rates.

The second limitation is with the detection bandwidth;
One of my secondary aims are to discover new applications for acoustic microscopy.
Although SRAS has been described previously [11, 4], current SRAS technology has been rather limited by the capabilities of current Q-switched lasers.

My secondary aim is to investigate the acoustic properties of multiferroic compound alloys such as Bismuth-Ferrite ($BiFeO_3$). Thin films $BiFeO_3$ have applications in strain engineering [12]

3 Progress so Far

The probing laser used in both my experiments is a mode-locked laser which has the following specifications: $\lambda = 780nm$, $\Delta\tau \approx 100fs$, master repetition rate 100MHz fixed, slave repetition rate 100MHz - 10kHz. For The pump laser a frequency doubler is used meaning the probe beam has a wavelength of 320nm.

3.1 Sagnac

I have created a Pump-Probe Sagnac interferrometer. It's design is illustrated in figure 1, The detection method is most viable when the synchronized with source of excitation of the acoustic waves imaged [13]. The Sagnac uses two polarizing beam-splitters to separate the probing pulse into two paths, the short path (x) and the delay path (y). Each pulse collides with the material surface with a time delay $\Delta\tau$. (x) and (y) are reflected back into the sagnac however pulse x returns via path y and vice-versa. When the two pulses are rejoined, a difference in optical phase caused by a difference in surface displacement can be directly measured. The sampling frequency of the whole system is limited by delay time between probe pulses x and y, which subsequently are limited by the pulse width and repetition rate of the probe laser.
Equation-(3) below calculates the relationship between sagnac length L and pulse delay $\Delta\tau$. For a pulse delay of 500 picoseconds, the length L of the sagnac arm must be approximately 75 millimetres.

$$c = \frac{\Delta d}{\Delta \tau} \qquad\qquad L = \frac{\Delta d}{2} \tag{3}$$

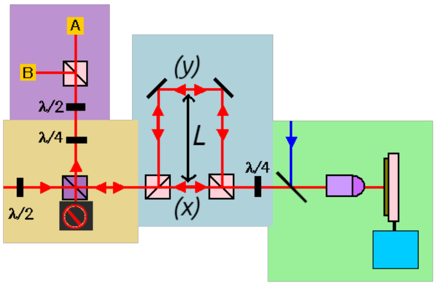
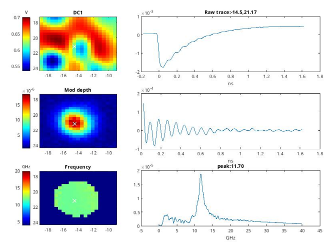


Figure 1: diagram of my Sagnac interferrometer, the design is based on [14], just like in [15], the Sagnac time delay is at 500ps however I have my apparatus set up in such a way that the time delay is easily adjustable

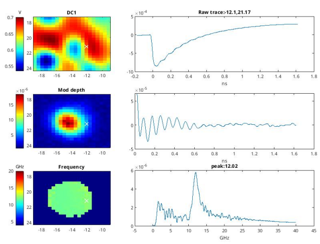
3.2 beam distortion detection technique

I measured acoustic waves on a Copper Sample using a beam distortion detection technique [?, ?]. beam distortion detection (BDD) methods are functionally identical to knife edges in the sense that both methods use the angular displacement of the reflected probing laser caused by surface distortion as a result of surface acoustic waves.
The BDD setup consists of a single photo-detector and an iris aperture (or alternatively a literal knife edge) whereas a knife edge uses a split diode circuit (effectively two detectors) in which the signal from one diode is subtracted from the other using a differential amplifier.

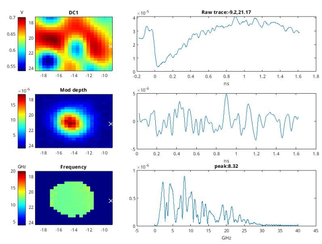
3.2.1 results



(a) center



(b) edge



(c) outside

Figure 2: co-peak data of sample at different points relative to the pump beam

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